METHOD FOR FINELY PROCESSING A CYLINDRICAL INNER SURFACE

BACKGROUND OF THE INVENTION

Field of the invention

[0002] The invention relates to a process for precision-machining a cylindrical inner surface in accordance with the preamble of claim 1.

Related Art of the Invention

[0003] The precision-machining of cylindrical surfaces, in particular the precision-machining of cylinder bearing surfaces in cylinder crankcases, is generally realized by honing. There are a wide range of publications in this respect, such as for example DE 44 32 514 A1, which describes a process allowing a highly accurate final dimension of a honed surface to be achieved.

[0004] DE 196 05 588 C2 describes a process in which a cylinder bearing surface is treated in such a way at a top dead center and bottom dead center of a piston that it is able to withstand higher wear conditions in these regions.

[0005] However, the known prior art is restricted to the precision-machining of a surface which has the same surface material throughout. However, the situation may arise whereby the cylinder bearing surface is formed by different materials. These are a softer region, which is formed, for example, by the cast material of the cylinder crankcase, and a harder region, which is formed by a cylinder liner.

[0006] In such cases, precision-machining, in particular honing, is particularly difficult, since the machining tools used, e.g.

the honing stone, becomes clogged by the softer material, thereby losing its abrasive action.

SUMMARY OF THE INVENTION

[0007] The object of the invention is to precision-machine cylindrical inner surfaces which have different materials in such a way that the service lives of the machining tools are considerably improved.

[0008] The solution to the invention consists in a process as claimed in claim 1.

[0009] The process according to the invention as claimed in claim 1 is distinguished by the fact that a cylindrical inner surface, in particular a cylinder liner which has at least one softer region and at least one harder region in the axial direction, is precision-machined by honing steps, a preliminary honing step (preliminary honing) and a precision-honing step (precision-honing).

[00010] In this context, the term honing is to be understood as meaning any type of precision-machining in which surface regions are removed by the action of abrasive particles. These abrasive particles are usually bound in a honing stone which is secured to a honing tool.

[00011] In the process, a cone which widens from the harder region to the softer region is introduced along a cylinder axis during the preliminary honing. During the precision-honing, this cone is compensated for in the harder region as far as approximately a

boundary between the harder region and the softer region, so that in the finished state a cylindrical surface is restored in the harder region. The cone is retained in the softer region.

[00012] The cone, which spans the boundary region between the softer and harder regions, prevents the extremely fine abrasive particles on a precision-honing stone from becoming clogged by the material of the softer region.

[00013] In one configuration of the invention, the cone is introduced by a conical honing stone or a honing stone which is oriented in the shape of a cone. The conical or conically oriented honing stone allows the cone to be predetermined by the tool so that it is accurately set.

[00014] In another embodiment of the invention, the cone is introduced by a conventional honing stone, the honing stone and the honing tool are controlled by the process parameters in such a manner that increasing amounts of material are removed along the direction of advance, which leads to the formation of the cone.

[00015] The process parameters which have the highest influence on the formation of the cone are a rate of advance of the honing tool along a cylinder axis and a contact pressure of the honing tool against the cylindrical inner surface.

[00016] In a further configuration of the invention, a plurality of types of honing stones are arranged on one honing tool and can be respectively extended or retracted according to the appropriate application (for example preliminary honing or precision-honing).

[00017] The cone which is introduced along the cylinder bearing surface according to the invention generally has a small change in radius amounting to between 10 µm and 100 µm. This change in radius extends over a length of between 20 mm and 200 mm along the cylindrical inner surface.

[00018] To avoid a separate step in the softer region, the cone can open out into an opposite cone, which leads to a convex shape in the softer region. The convex shape can contribute to reducing noise when the engine is operating.

Brief Description of the Drawings

[00019] Advantageous embodiments of the invention are explained in more detail with reference to the following drawings, in which:

Fig. 1 shows a section through an unmachined cylinder liner having a harder region (at the top) and a softer region (at the bottom),

Fig. 2a shows preliminary honing using a conically oriented honing stone,

Fig. 2b shows preliminary honing using a straight honing stone,

Fig. 2c shows preliminary honing using a honing tool equipped with two types of honing stones, and

Fig. 3 shows a cylinder liner in the finish-honed state.

Detailed Description of the Invention

[00020] Figs 1 to 3 illustrate the process according to the invention in simplified form, with Figs 2a-c showing alternative configurations for the introduction of a cone 11.

[00021] Fig. 1 illustrates an unmachined cylinder bearing surface 2 in cross section. The cylinder bearing surface 2 is divided into a harder region 4 and a softer region 6. The transition 14 between the regions is discrete in this embodiment, but a gradual transition is also conceivable.

[00022] The harder region 4 of the cylinder bearing surface 2 is usually formed by a cylinder liner, which consists, for example, of a hypereutectic aluminum-silicon alloy. In the present example, the alloy has a silicon content of approx. 25%. The high silicon content leads to a high hardness for aluminum alloys. In the present example, the softer region 6 consists of a conventional die-cast aluminum alloy.

[00023] If appropriate, the cylinder liner is machined by preliminary turning (not shown in the figures), so that relatively coarse regions of the surface caused by production conditions are smoothed for the subsequent honing operation.

[00024] In a subsequent process step, a honing tool 7 having - generally a plurality of - honing stones 8 is introduced into the cylinder liner 2. The honing stones 8 on the honing tool 7 are oriented obliquely with respect to an axial direction (cylinder center axis) 9, so that a cone 11 is formed along the cylinder bearing surface 2. It is also expedient for the honing stones 8

themselves already to be conical in form.

[00025] The length 10 of the cone 11 is approximately 100 mm, and its radius change 12 is approximately 20 µm. It should therefore be noted that the cone shown in Figs 2a-c and Fig. 3 is illustrated in greatly exaggerated form, in order to improve the clarity of the drawing.

[00026] The honing tool 7 having the honing stones 8 is moved firstly with an advance V along the cylinder center axis 9 and is also rotated about its own axis, and in addition the honing tool 7 describes a rotary motion along a wall of the cylinder bearing surface 2.

[00027] The honing stones 8 which are used for the preliminary honing are preferably covered with diamonds as abrasive particles. The diamonds have a larger mean diameter than the abrasive particles which are used in the precision-honing.

[00028] During the advance V of the honing tool 7, the honing stone 8 is moved over the harder region 4 of the cylinder liner 2, and goes beyond the transition 14 to the softer region 6. The coarse abrasive particles are configured in such a manner that they do not become clogged by the aluminum alloy in the softer region 6. Consequently, the service life of the honing stone 8 is not adversely affected to a significant extent.

[00029] Analogously to the process described with reference to Fig. 2a, in a further embodiment shown in Fig. 2b, a conventional honing tool 7', in which honing stones 16 are oriented

substantially parallel to the cylinder center axis 9, is used to form the cone 11. The cone 11 is introduced in such a manner that the advance V in the direction of the softer region 6 is decelerated appropriately and/or the dwell time at a lower turning point of the honing tool 7' is extended appropriately.

[00030] In addition, it is possible to increase the contact pressure P against the cylinder bearing surface 2. The abovementioned measures cause the amount of material removed to be increased in the corresponding region. The parameters advance V, dwell time and contact pressure P are adjusted by a suitable control unit in such a manner as to form the cone 11 according to the invention.

[00031] In a third configuration of the invention described here, as shown in Fig. 2c, a honing tool 18 which includes (at least) two types of honing stones is used; these honing stones can be extended and retracted as required. A honing tool 18 of this type is also referred to as a double-widenable honing tool.

[00032] The double-widenable honing tool according to the invention includes at least one set of honing stones 20 for preliminary honing and a set of honing stones 22 for precision-honing. Therefore, there is no need to exchange the honing tool 18 for the precision honing, which is described in more detail below.

[00033] For the preliminary honing, the double-widenable honing tool may optionally be equipped with a honing stone set at an angle as shown in Fig. 2a or may be subjected to appropriate control as shown in Fig. 2b. The cone 11 is formed in both cases.

[00034] Following the alternatives illustrated in Figs 2a-c, the harder region 4 is precision-honed to the desired tolerance and surface condition using a precision-honing stone 26, 22 (Fig. 3). After the precision-honing, the cylinder liner 2 in the harder region 4 is cylindrical (or virtually cylindrical depending on the particular requirements) in form, as is required for optimum piston movement.

[00035] The cone 11 is retained in the softer region 6 and merges into an opposite cone 30 in order to avoid an undesirable step. The remainder of the cone 11 and the cone 30 form a convex shape 28 in the softer region 6.

[00036] This convex shape in the lower region of the cylinder liner leads to better piston guidance and to a significant reduction in the piston noise, and accordingly improves comfort when the engine is operating.